Lec8: Equivalent circuit & Efficiency of transformer

outline:

1. Electric Equivalent circuit of single Phase transformer
2. calculation of losses & Efficiency

Transformer
- Principle of operation & Construction
- emf equation & turns ratio
- No load & loading cases
- Equivalent circuit & Efficiency

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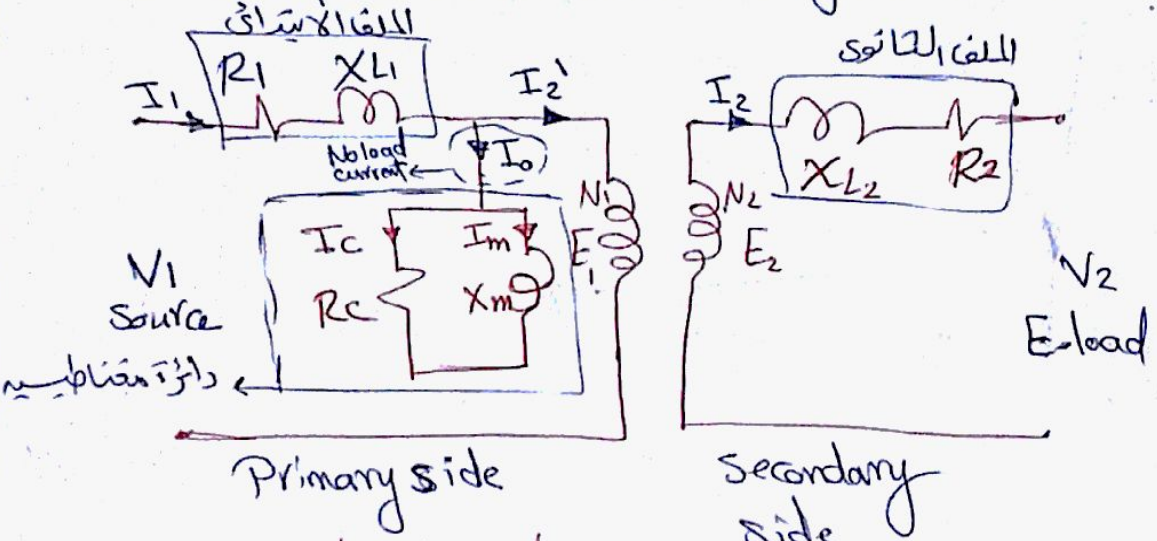
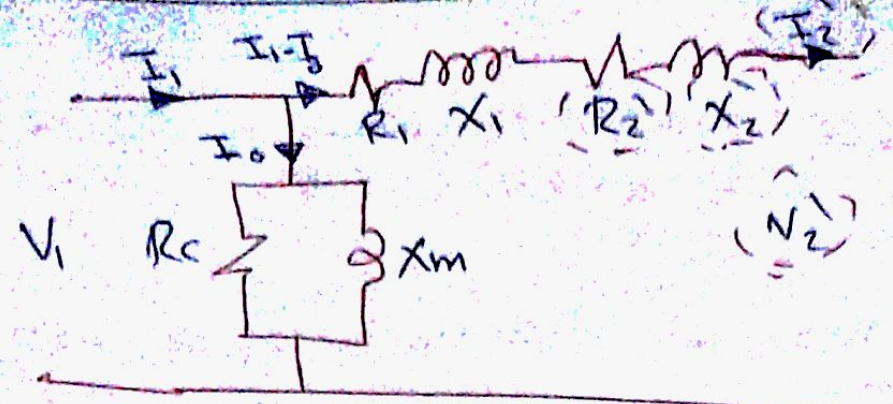
1. Equivalent circuit of single Phase transformer.



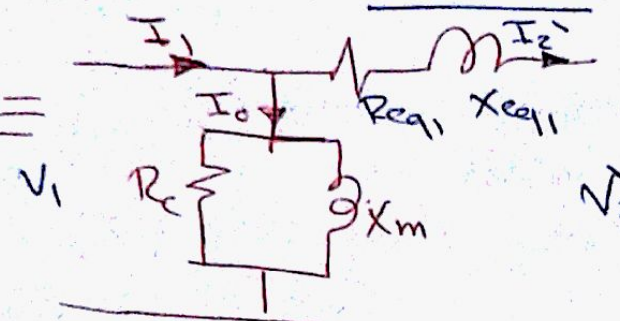
* Equivalent circuit of 1-ϕ transformer.

R_1 & R_2 : Primary and secondary resistance (Ω)
X_1 & X_2 : Primary and secondary inductance reactance (Ω)
N_1 & N_2 : No of turns of Primary & Secondary
I_o : No load current (A)
I_c : Core losses Current (A)
I_m : magnetizing Current (A)
V_1 : Voltage of Source (V)
V_2 : terminal Voltage (V)
E_1 & E_2 : induced emf in Primary & Secondary
R_c : resistance of magnetizing circuit
X_m : reactance of magnetizing circuit.



Equivalent circuit referred to Primary side

الدائرة المكافئة المنسوبة إلى الملف الابتدائي



$$X_{eq_1} = X_1 + X_2'$$
$$R_{eq_1} = R_1 + R_2'$$
$$Z = \sqrt{R_{eq}^2 + X_{eq}^2}$$

$$I_2^2 R_2 = I_1^2 R_2'$$
$$R_2' = R_2 \left(\frac{I_2}{I_1}\right)^2 = R_2 \left(\frac{V_1}{V_2}\right)^2$$

$$\boxed{R_2' = R_2 \left(\frac{N_1}{N_2}\right)^2}, \quad \boxed{X_2' = X_2 \left(\frac{N_1}{N_2}\right)^2}$$

$$\therefore X_{eq} = X_1 + X_2' = X_1 + X_2 \left(\frac{N_1}{N_2}\right)^2$$
$$R_{eq} = R_1 + R_2' = R_1 + R_2 \left(\frac{N_1}{N_2}\right)^2$$

* لو أهملنا المقاومة في الدائرة المغناطيسية فإن $I_1 \simeq I_2'$

Example: A transformer has 600 primary turns & 150 secondary turns. the primary & secondary resistance are 0.25 Ω, 0.01 Ω respectively. the corresponding leakage reactance are 1 Ω, 0.04 Ω respectively

Find @ Equivalent circuit referred to primary winding

ⓑ " " " secondary winding

Given:

$N_1 = 600$, $N_2 = 150$, $R_1 = 0.25\ \Omega$, $R_2 = 0.01\ \Omega$

$X_1 = 1\ \Omega$, $X_2 = 0.04\ \Omega$

@ $R_{eq_1} = R_1 + R_2'$, $X_{eq} = X_1 + X_2'$

ⓑ $R_{eq_2} = R_1' + R_2$, $X_{eq} = X_1' + X_2$

I_1 (التيار الأصلي) ← I_2 (loading current) تيار الحمل
I_o ← I_m = flux (ϕ) (المستعمل في توليد المجال المغناطيسي)
I_c ⇒ (losses) تمثل المفاقيد

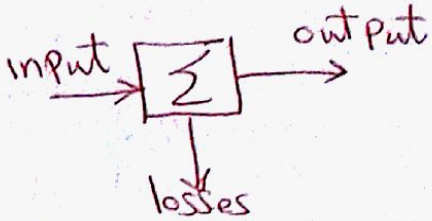
*** سؤال كويس

- Explain the losses of [DC machine, transformer,]

اشرح المفاقيد في (المولد، المحرك، المحول) ⇐

** Losses in transformer

- Copper (Electrical) losses
- Iron (Magnetizing) losses
- No Mechanical losses



input = output + losses

* قيمة كفاءة المحول إلى 98,99%

Efficiency of transformer ٪ "eta"

$$\eta\% = \frac{x S \cos\theta}{x S \cos\theta + P_{core} + x^2 P_{cu}} * 100\%$$

S = rating of transformer [KVA] = $I_{rated} * V_{rated}$
x = fraction of loading نسبة التحميل
$\cos\theta$ = Power factor of load
P_{cu} = Cupper losses المفاقيد النحاسية = $I_1^2 R_1 + I_2^2 R_2$
P_{core} = Core losses المفاقيد الحديدية

Max efficiency occur at $x = ?$

$$\eta_{max}\% = \frac{S\cos\theta}{S\cos\theta + \frac{P_{core}}{x} + xP_{cu}}$$

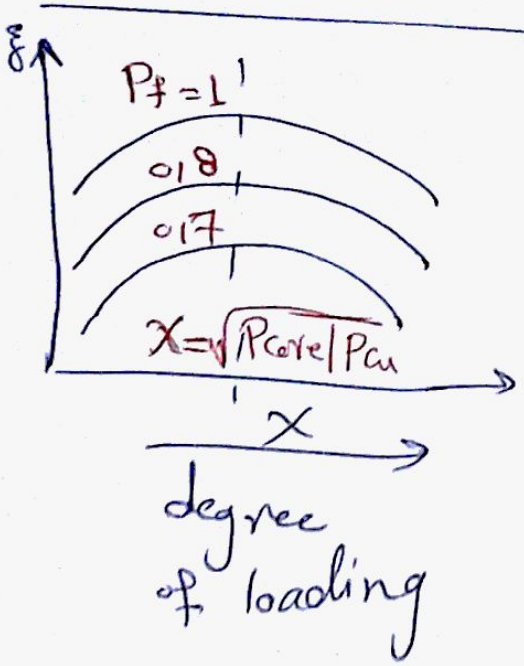
$$\frac{d}{dx}(\text{denomiator}) = \text{Zero}$$

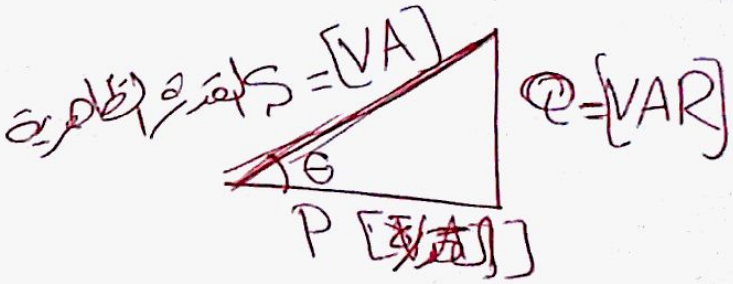
$$\frac{d}{dx}\left(S\cos\theta + \frac{P_{core}}{x} + xP_{cu}\right)$$

$$x^2 P_{cu} = P_{core}$$

شرط الحصول على اقصى كفاءة

$$\therefore x = \sqrt{\frac{P_{core}}{P_{cu}}}$$





* عند حساب الكفاءة بدلالة (x)
* عند حساب اقصى كفاءة (x) تحسب
$x = \sqrt{P_{core}/P_{cu}} = []$
* تحسب بقيمها الكفاءة بالتعويض بقيمة (x) في المعادلة الرئيسية